Art. I.—*The Examination of Waters.*

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This subject, being one of the very greatest importance to the well-being of any community, has at the present day a literature of its own in almost every modern language, and numbers of able men—engineers, medical men, microscopists, and chemists—are devoting themselves to the study. The results of their labours show the necessity of having pure drinking water, and the absolute elimination of all possible sources of contamination by sewage matter.

For a number of years past I have been examining, in a more or less irregular manner, the waters of Victoria—in former years, with the assistance of the late Mr. Manley Hopwood and my late assistant, Mr. Frederic Dunn, now our public analyst, and more recently with Mr. Savage and Mr. Dunn. Some of our analytical results have appeared in the publications of the Department of Mines; and I must admit that if these are taken into consideration without full knowledge of all the circumstances connected with the method of collection and the sources of supply, they form a most confusing table, and without such information give but little idea of the real condition of the water from a sanitary point of view, especially when taken singly. For instance, an undoubtedly contaminated well-water from Kyneton gave us in parts per million: Free ammonia, 0·19; albuminoid ammonia, 0·22; while rain-water from the Observatory gauge gave: free ammonia, 1·088; albuminoid ammonia, 0·947. The rain-water was the first which fell after a long drought, and had washed a contaminated atmosphere.

A chemist may, by any of the well-known methods, determine the amount of nitrogenous matter contained in the water, as free or saline ammonia, albuminoid ammonia, nitrites or nitrates, and from the results obtained, with or without an estimation of the amount of combined carbon and chlorides present, form some idea of its character; but

these determinations do not prove in the slightest degree whether the water is fit to drink, or whether it carries the germs of disease, ready and able to reproduce the disease whenever any one of the germs may meet a suitable subject.

When the results obtained are what may be considered abnormal, they simply show that a source of contamination should be sought for; and for this reason these tests should be continually applied to all our large sources of public supply. The determination of combined carbon and chlorides seems to me to be of less value here than in England, for all our surface waters are more or less saline, with the exception of those derived from the mountain ranges and the more elevated portions of the colony. Many of the streams in the more level parts of the colony become brackish during droughts, or in our ordinary summer weather; and an idea of the amount of salt these streams carry may be formed when we look at the lakes in the Western District, and see that all those which have not some natural outlet become strong brines during the summer months, though they are filled by streams of almost tasteless water in the winter; they yield annually many tons of salt to the factories. In most of our river valleys we have numerous mineral springs, many of them yielding waters charged with alkaline carbonates; and these alkaline salts, acting upon the dead organic matters, dissolve some of the carbonaceous substances, and carry it into the stream and reservoirs. These facts show that we must be very careful in drawing conclusions from our analytical results. If we have some previous knowledge of the impurities in a water, our analysis will, however, indicate any changes that may be taking place, and the necessity for a careful examination of the sources of supply. For instance, in the year 1877 the waters from the Geelong supply gave as an average in one million parts, 0·00085 of a part of free or saline ammonia, and 0·0076 of albuminoid ammonia, and still less nitrogen as nitrites or nitrates. The water which had been cleared by lime contained only a little more than one-half of the quantity of albuminoid ammonia given in these small fractions, and the people of Geelong flattered themselves that they had one of the purest water supplies in the colony.

At the present time we find 150 times as much free ammonia, and of albuminoid ammonia nearly 200 times as much, besides a very notable amount of nitrites and nitrates

—over three per million. A similar statement may, I am afraid, be made with regard to almost every public water supply in the colony, except Yan Yean, which, owing to the great care taken, is steadily improving, and, apart from its colour, is an exceptionally pure water.

The figures just given do not prove that the water is poisonous; and we know that the people of Geelong who drink this water have not suffered more, or as much, from typhoid fever—the real filth disease—as the people who are drinking the purer Yan Yean; and this argument, amongst others, is used to prove that though the water has chemically deteriorated to such a great extent, it is still a wholesome water. To investigate it further, I tried to follow the experiments described by the late Dr. Angus Smith in his last report to the Local Government Board of Great Britain, dated 1884, and convinced myself that the water was directly contaminated by filth. I found many difficulties in following Dr. Smith's experiments; but even though not successful in proving the quantity or energy of the contamination, I found no difficulty in developing a large variety of bacteria only to be found in filthy water, or water contaminated by filth. I find similar bacteria in the waters from both branches of the Moorabool, Lal Lal Creek, Stoney Creek reservoir, some cattle tanks near the Anakies, the Clunes supply, the Coliban, the Wimmera at Dimboola, the Horsham supply, and several others.

I feel considerable diffidence in naming the various forms which I have observed, as some do not agree with the descriptions given by the "best authorities," and of late we have seen that these same "best authorities" do not agree with one another, not only about the name a certain form shall take, but also as to whether these interesting micro-organisms are vegetables or animals. I have no doubt, however, that I have recognised in the waters named all the common types of bacteria which always accompany filth. The greatest variety of forms are to be found in the water from the Western Moorabool and Lal Lal Creek, and they may be developed by any of the ordinary means in such numbers in a bottle of either of these waters that in a short time it is simply a bacteria jelly with an offensive, sickly smell. The number developed may in some measure have prevented my being successful with Dr. Smith's gelatine method, as these organisms render a thin gelatine jelly liquid, and if the

jelly is too stiff they do not seem to have the power to act. At the time I was making my experiments the temperature of the laboratory often rose to 80° F., and, as at this temperature the 5 per. cent. jellies became liquid, the bacteria were able to move freely through the tubes, the experiments were lost.

I then used the well-known solutions of tartarate of ammonia, phosphate of sodium, sugar, and nitrates, singly and mixed, having previously carefully sterilised them by boiling, and using precautions to prevent outside contamination, and as a check testing distilled water contaminated by the air of the laboratory. In these experiments the Yan Yean (filtered) was the only natural water which would not develop its germs without the addition of ammonium tartarate. When mixed with sugar the mud separated from the Yan Yean water by a high-pressure filter produced alcohol—(another exception, which can hardly be called a natural water, is the water from the Lovely Banks Reservoir, which has been treated by lime)—while all the other waters became offensive, producing ropy liquids undergoing putrefactive changes, giving off hydrogen, and smelling at times of butyric and lactic acids.

Most of my experiments were repeated several times, and I noted that in those waters which contain the germs of many varieties of bacteria the sequence of development and duration of the existence of each class or variety might be varied by slight alterations in the method of treatment; and this may in some measure account for the contradictory statements made by scientific observers as to the types found in certain waters, and the chemical changes produced by them. With this part of the subject I hope to be able to deal at a future time, but in this inquiry I was satisfied in obtaining evidence which confirmed the results of the chemical tests, proving the contamination by filth, and that the germs introduced by this filth contamination were still active. While these experiments were being conducted I had the opportunity of visiting one of the watersheds in question —the Moorabool—under the guidance of Mr. Wm. Davidson, the engineer of the Yan Yean Water Supply, and found that the river, with its tributaries, is simply the drain of a pastoral and farming district, with a rapidly increasing farming population.

Some pure water may get into the river from springs along the banks, and before the recent rain these springs

may have contributed a considerable proportion of the very limited stream, and at the same time account for the large amount of saline matter present, amounting to from 16 to 20 grains per gallon. But after the rain the main supply will come from the small tributary streams and soakage, the best of which will take their supply from well-stocked pastures and farm lands, and the worst from farmyards, piggeries, dwellings, and closets. A glance at a recent map of the colony will show that a similar state of affairs must exist, more or less, in the collecting area of most of our water-supply schemes, Yan Yean excepted. I am told that the Yan Yean catchment area does not receive the drainage of a single dwelling of any kind, and this statement proves the accuracy of the methods of detecting filth. We found none. The future management of the other schemes will, I fear, tax the energies of our engineers if they are called on to give pure water, for as population increases these waters must become worse. I don't wish to meddle with the medical aspect of the case beyond my own sphere; but we all acknowledge that typhoid fever is only communicated by means of excreta, that it is essentially a filth disease, that it is now very prevalent throughout the colony, and that water is the best possible carrier of the disease. What I have shown proves—first, chemically these waters should be suspected; second, microscopically they contain living forms, only found in connection with filth; and third, in the case of the Moorabool, ocular demonstration may be obtained of direct pollution; and I have no doubt I should have found the same evidence of pollution on visiting the other watersheds in the populated districts. It may be asked why, with such a foul watershed for its supply, Geelong has not suffered more from typhoid fever; and there are, I believe, known cases within the water supply area. The answer, I think, is, that the source of supply has been dry while typhoid has been prevalent, and that there is no intake to the reservoirs, and that the method of treatment of the water by lime at the Lovely Banks Reservoir to a very great degree destroys the living germs. To what extent this lime treatment may be effective in killing fever germs is unknown. It prevents the development of Stoney Creek Reservoir bacteria; but in the Lovely Banks water I find certain minute living cells, and the presence of life of any kind throws a doubt upon the value of the process. Somewhat similar means are adopted to

purify the water drawn from the Thames for the supply of London. Above the point at which the water is taken there is a very large population; but the circumstances are not similar to ours; and compared to the Moorabool or smaller streams which supply the reservoirs in question, the Thames is a great river, and chemical changes caused by the very filth that falls into it may tend to purify it; and, further, we can have no evidence whatever of the amount of disease that it actually conveys. I may quote from an essay on water supply, by J. H. Balfour Brown, lent to me by Mr. Davidson. He says, in writing of purified sewage:— "Common sense is revolted by water which is mixed with sewage, and although common sense is often behind science, in many cases, like children who stray before grown-up people, it runs before. The chemist cannot point to the specific infecting substance, but can tell you whether the water is open to suspicion; whether it is injurious to health can only be determined by physiological tests. Dr. Frankland, than whom we have no greater authority, says normal sewage may be drunk with impunity; water mixed with healthy sewage is quite wholesome to drink; probably half the population of the country (England) are drinking such water." But what happens if the sewage is not healthy? I need not quote the well-authenticated instances in which one single individual has contaminated a water supply, and by this means has communicated the disease to hundreds; of how in the village of Lausen the poisoned water had to filter through a mountain range before it reached the victims, and yet the filtering power of the mountain rocks through which the water passed was sufficient to prevent the passage of starch granules, showing that there was no fissure or channel through which to convey solid particles. Nearer home we have an instance that would be worth investigating. The New South Wales Government made soakage dams below the new town of Silverton, in a direct line with the natural drainage, and during the late drought all water had to be obtained from these dams or wells in the sand. Typhoid was taken to the new town, and in a very short time the local hospital was too small to hold the number of typhoid patients. Recently we have had numerous filters devised which pretend to prevent the passage of germs, but at present I have not met with one or been able to make one which answers the purpose. The high-pressure filters now coming into common use, in which there is a cell of earthen-

ware, will separate the minute bacteria forms from the Yan Yean, but the beautiful, bright filtered water obtained from this filter contains their germs. Some good scientific observers claim to have made filters which will separate germs; but it is possible, I think, that they have been experimenting on water in which the bacteria were exhausted or dying, and in which there were no germs; for after they (the bacteria) have brought about the chemical changes of which they are capable they do die out; and it has been a point of interest to watch how each of the waters under examination passed through its various stages, and one form replaced another till all died. Whether we ever reach a stage in which there are no germs present I am not certain, but think that it is probable, and that in the rapid changes the disease germs may suffer in the same way as harmless bacteria. Bacteria are so easily killed, and it is so easy to destroy, or perhaps I should say prevent, their germs from developing that we may hope for some means for in a like manner destroying disease germs, and I think some simple salt may do this.

But, as Mr. Balfour Brown says, for proof in connection with this subject "we must be content to wait for the fuller revelation, which may be reached through long bills of mortality in time to come;" and quoting from Dr. Cayley's Croonian lectures, "I think these two instances (the Catherum and Lausen cases) are sufficient of themselves to serve as a warning against trusting to irrigation and downward filtration as a means of purifying water, and also against the dictum that water containing less than a certain proportion of organic impurity is practically wholesome and fit for drinking irrespective of its original source. It ought, I think, to be laid down as a rule of hygiene that human excrements should under no circumstances be mixed with drinking water, however completely they may be subsequently removed by filtration or rendered innocuous by oxidation. Of course, in the case of London this can only be looked upon as an ideal to be realised in some distant future; but with less than this we ought not to rest satisfied." "Living matter," says Dr. Alfred Hill, "does not get oxidised by flowing down a stream any more than a fish. It is not decomposing animal matter which is prejudicial, but actual living matter. Mere dilution by water does not deprive it of its dangerous qualities." Dr. Frankland says: "I do not think it possible by any practical means that have been

suggested so to purify water as to guarantee its freedom from these germs of disease." And these authorities believe that "if a spoonful of unhealthy sewage is put into the Thames at Oxford it may poison some persons in London."

In a recent article in the *Argus* I noticed a statement that during the epidemic of cholera in Italy none of the people employed in the manufacture of borax, or in connection with the works, were attacked by the disease. The claims of borax as a disinfectant and preservative for food have been advanced a great many times of late years, but without much success. But seeing the statement referred to, I added a boiled solution of borax to some freshly filtered water, together with sterilised ammonium tartarate and sodium phosphate, and though the bottle has stood in the laboratory for 30 days there are no bacteria yet to be found in it. The same water, treated in the same way, but without borax, becomes cloudy with bacteria in two or three days; and in the same water unfiltered, in which there are developed bacteria, the borax has no effect; the increase in number goes on just as rapidly with as without it. This explains some of the contradictory results obtained with borax and boracic acid. It has some effect on the germs, but not on the developed bacteria. If the statement from Italy is true, and I see no reason to doubt it, the explanation seems to be that all the water about the borax works contains this salt, and the workmen are continually taking it into their systems, and that the germs became passive, or died in the borax water. On fully active bacteria I have tried the action of several so-called disinfectants, and find that dilute solutions have little or no effect. They swim about in a distinctly purple solution of permanganate of potash, and seem to reject it; and 1 per cent. carbolic acid takes a long time to kill them. Lime water kills them, but not if too dilute; but lime-like borax seems to prevent the growth of the germs, and a mere trace of benzine destroys both germ and bacteria, and probably most hydro-carbons do the same; and we may yet have to return to the work of the late Dr. Day, of Geelong, and study the action of hydro-carbons, and the formation of peroxide of hydrogen, and there find our best disinfectant. These crude experiments, with which I do not offer any figures, as I do not yet know the minimum quantity of disinfectant required, suggest many others. Though it is possible that some means may be found to prevent infection by killing germs in poisonous waters, I

hardly think that any portion of our community will be satisfied to accept as a water supply one which may largely consist of sterilised sewage.

TABLE SHOWING NITROGENOUS MATTER IN SOME OF THE WATERS REFERRED TO.

(Amounts given in parts per million.)

Locality.	Free Ammonia.	Albuminoid Ammonia.	Nitrates and Nitrites.	
OBSERVATORY GAUGE—				
January ...	0·1088 ...	0·0947 ...	0·1334	
Mar. 14th & 15th	0 5598 ...	0 0799 ...	0·2499	
,, 15th ...	0·3998 ...	0 0622 ...	0·1419	
,, 31st ...	0·0999 ...	0 0499 ...	0·1500	
April 17th ...	0·2503 ...	0·1001 ...	0·2002	
,, 21st ...	0 2002 ...	0·0500 ...	0·3002	
,, 26th ...	0·1000 ...	0·0500 ...	0·4005	
May 10th to 15th	0·2603 ...	0·1001 ...	0·4505	
,, 30th to 31st	0 3103 ...	0·1939 ...	0 2326	
June 7th to 13th	0·0640 ...	0·0512 ...	not determined	
,, 13th to 14th	0·2560 ...	0·1152 ...	,,	
,, 17th to 20th	0·3712 ...	0·1920 ...	,,	
Museum Yard, Jan.	0·0788 ...	0·0710 ...	0 12	
,, ,,	0·1261 ...	0 0788 ...	0·123	
Observatory gauge, Thunderstorm Jan.	2·3790 ...	0·6608 ...	0·395	after long drought, 21st January, 1879
MT. MACEDON GAUGE—				
April ...	0·5914 ...	nil ...	0·045	
May 26th to 30th	nil ...	,, ...	nil	
Sept. 22nd to 27th	0·3984 ...	0·1092 ...	0 3664	
Oct. 7th to 18th	nil ...	nil ...	nil	
,, 18th to 19th	0·225 ...	,, ...	0·1992	
Nov. 24th to 26th	0·623 ...	0·0900 ...	0·3985	
Dec. 18th & 19th	0·4564 ...	0·1092 ...	0·2185	
,, 19th ...	0·2828 ...	0·1671 ...	0·3985	
Yan Yean Reservoir	0·1001 ...	0·2003 ...	0 3004	9th February, 1880
Middle ,, ,,	0·0200 ...	0·4500 ...	undet.	3rd May, 1880
Plenty River ...	nil ...	0·1001 ...	,,	23rd February, 1881
Yan Yean Intake ...	0·0350 ...	0·1001 ...	,,	22nd January, 1881
West Moorabool ...	0 0265 ...	0 106 ...	0 119	March, 1885
Fiskin's Dam ...	0·1326 ...	0·437 ...	0·424	,, ,,
Connell's Dam ...	0·0928 ...	0·452 ...	0·331	,, ,,
Stoney Creek Resvr.	0·0133 ...	0·146 ...	0·332	,, ,, Geelong
Lovely Banks ,,	0 0199 ...	0 081 ...	0·292	,, ,, Supply
Geelong Supply ...	0·0006 ...	0 013 ...	nil	1877
,, ,, ...	0 0009 ...	0·007 ...	,,	,,
,, ,, ...	... ...	0·0046 ...	,,	,, Lovely Banks Resrvr.